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CONSIDERATIONS IN DEVELOPMENT AND IMPLEMENTATION OF ELASTO-VISCOPLASTIC CONSTITUTIVE MODEL FOR HIGH TEMPERATURE APPLICATIONS

by

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Extended Abstract

The prediction of inelastic behavior of metallic materials at elevated temperatures has increased in importance in recent years. The operating conditions within the hot section of a rocket motor or a modern has turbine engine present an extremely harsh thermomechanical environment. Large thermal transients are induced each time the engine is started or shut down. Additional thermal transient from an elevated ambient, occur whenever the engine power level is adjusted to meet flight requirements. The structural elements employed to construct such hot sections, as well as any engine components located therein, must be capable of withstanding such extreme conditions. Failure of a component would, due to the critical nature of the hot section, lead to and immediate and catastrophic loss in power and thus cannot be tolerated. Consequently, assuring satisfactory long term performance for such components is a major concern for the designer.

Non-isothermal loading of structures often causes excursion of stress well into the inelastic range. Moreover, the influence of geometry changes on the response is also significant in most of the cases. Therefore both material and geometric nonlinear effects must be considered.

In previous papers[1,2] the authors have presented a constitutive law for thermo-elasto-viscoplastic behavior of metallic materials, in which the main features are: (a) unconstrained strain and deformation kinematics, (b) selection of reference space and configuration for the stress tensor, bearing in mind the rheologies of real materials, (c) an intrinsic relation which satisfies material objectivity, (d) thermodynamic consistency, and (e) proper choice of external and internal thermodynamic variables. A brief description of this constitutive equations is given in the present paper.

To use this model effectively and reliably for the analysis and design of hot section structural components, we must demonstrate its feasibility to model the behavior of realistic materials and its incorporation in nonlinear finite element structural analysis code and perform nonlinear stress/life analysis for these

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components (including phenomena like creep, relaxation, ratchetting, etc.).

Within the developed frame the elasto-thermo-viscoplastic behavior is governed by the scalar material functions of the internal variables and temperature. These material functions can be determined from a series of monotonic and cyclic processes with proportional and nonproportional paths at different temperature levels. Unfortunately there is a lack of suitable experimental data against which this functions can be evaluated.

The present paper reports some preliminary evaluation of these material functions for two materials, the IN100 and the Hastelloy-X based on the experimental data from a series of experiments performed at NASA-Lewis Research Center. These examples clearly demonstrates how the general constitutive relations can be applied to a particular real material. These material laws are then applied to the remaining examples.

Next, the integrability and the numerical performance of these constitutive equations is evaluated. In the final stage the ability of these formulations to model such behavior as creep and ratchetting is demonstrated by two examples. The first of thick cylinder and the other of thin panel.

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